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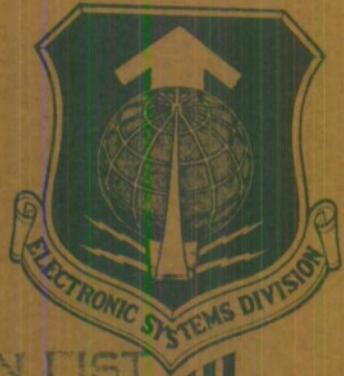
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AIR FORCE MANAGEMENT OF COMPUTER  
PROGRAM ACQUISITION

Joseph L. Pokorney, 1st Lt, USAF

August 1966



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TECHNICAL REQUIREMENTS AND STANDARDS OFFICE  
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## FOREWORD

Information contained in this report was presented at the Air Force Systems Command Junior Officer's Scientific and Engineering Symposium, 23-25 August 1966, Aerospace Medical Division's USAF School of Aerospace Medicine.

## REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

  
FRANK E. BRANDEBERRY, Colonel, USAF  
Chief, Technical Requirements and  
Standards Office

## ABSTRACT

This paper describes an Electronic Systems Division effort to adapt the AFSCM 375 series and AFSCM 310 series management techniques to computer program acquisition. These techniques are unique in that they provide the first standardized management approach to computer program design and development. A complete process of management procedures that has been developed for management of computer programs during definition and acquisition phases is discussed. Particular emphasis is placed on an extensive change package to AFSCM 375-1 Configuration Management During Definition and Acquisition Phases and a package of computer program data items for insertion in AFSCM/AFLCM 310-1 Data Management proposed by Electronic Systems Division of AFSC. The concepts of uniform specifications, baseline management, change control, specification maintenance and accounting and standard data items as they apply to computer programs are discussed and the impact of applying these techniques to System Programs is analyzed.

## INTRODUCTION

In the development of large scale computer based systems, the application of management techniques to the design and development of computer programs has lagged far behind the management of hardware acquisition. While the concepts of uniform specifications, baseline management, change control, etc., described in the AFSC 375 series documents were titled "System Management Techniques", these techniques had been devised to manage hardware acquisition and did not cope with the peculiarities of computer programs. A number of reasons account for the reluctance of the Air Force to manage computer program design and development. Primarily, the computer program was an elusive and intangible object. It could not readily be seen or felt and thus it could not be easily described. The computer program was not hardware, nor was it data. It was easy to change the computer program to correct design deficiencies and to avoid redesign of hardware, but it was soon realized that uncontrolled changes created total confusion. Thus, the computer program defied description. The mystery associated with computer programs created numerous management problems. Detailed technical requirements were not specified prior to computer program design. Interfaces between computer programs and hardware or personnel were not specified and expensive incompatibilities were often designed into systems. Sufficient documentation was not provided for the computer program and often the user was never able to operate the system effectively. The lack of management techniques for computer program development was creating expensive overruns and costly systems that failed to satisfy user requirements.

## RELATIONSHIP TO 375 SERIES DIRECTIVES

The existing Systems Command 375 Series management procedures establish uniform requirements for system, equipment, and facility contract end

item specifications. Techniques for establishing baseline management, implementing change control and conducting design reviews are also provided. Unfortunately, none of these techniques address computer programs. The computer program, being an integral part of many systems, naturally had to be considered in this uniform management approach to provide system compatibility. An examination of Air Force Systems Command 375 management techniques indicated that many of these so-called "Systems Management Techniques" could be adapted to the management of computer program design and development. An effort was thus initiated at Electronic Systems Division to adapt the 375 series procedures to the management of computer programs. The fundamental concept of this approach was to define computer programs, i.e., a sequential list of digital computer instructions on magnetic tape, punched cards, etc., as a deliverable contract end item. The Computer Program Contract End Item (CPCEI) is similar in many ways to an equipment CEI as defined in AFSCM 375-1 Configuration Management During Definition and Acquisition Phase (I). It is a deliverable item that is formally accepted by the procuring agency. It is the prime level for management control and accountability and for preparing technical manuals. The CPCEI is described by a design/requirements specification in the same manner as equipment CEIs are described by a Part I CEI Specification (I).

Once the computer program was defined as a CPCEI, it was determined that many of the concepts of existing 375 series manuals and other research and development directives could be adapted to management of the CPCEI. Specifically, the concepts of uniform specifications, baseline management, change control, specification maintenance, design reviews and a test program were deemed necessary for adequate management of computer program development.

## UNIFORM SPECIFICATIONS

The uniform specification program (1) defines the system specification and the CEI specification that comprise that system. The system specification presents the design/performance requirements that the system must meet. Thus, it provides the basis for development of both hardware CEI specifications and computer program CEI specifications. The CPCEI specification (2) is written in two parts in the same manner as hardware CEI specifications, as described in AFSCM 375-1. Part I of the CPCEI specification provides the design/performance requirements and Category I qualification test requirements for the CPCEI. It consists of a detailed description, in operational and mathematical language, of the functions to be performed by the CPCEI. The Part I specification is the basis for design and development of the CPCEI and contains the requirements against which the CPCEI is tested. Part II of the CPCEI specification is a detailed technical description of the CPCEI as delivered. It contains a technically oriented description of the functions, structure, data base organization, etc., of the CPCEI including detailed flow-charts and source statement/machine language listings. Following its completion, the Part II specification constitutes a reference to assist the user in diagnosing troubles, designing modifications and implementing changes. As such, its technical accuracy and completeness must be assured prior to its acceptance by the Air Force.

## BASELINE MANAGEMENT

A baseline is defined as: "An approved and defined point of departure for control of future changes in system or computer program/equipment performance

and design. Each baseline is technically defined by a specification and typically, a system would have three unique baselines, as shown in Figure I: the Program Requirements Baseline defined by the system specification; the Design Requirements Baseline defined by the Part II CEI specification; and the Product Configuration Baseline defined by the Part II CEI specification. Baseline management, then, is the establishment of accurately defined baselines and the implementation of procedures to control changes to these baselines and insure that the system, as delivered, reflects all approved changes.

### CHANGE CONTROL

Change control and specification maintenance form the cornerstones of baseline management. Change control establishes systematic procedures for proposing changes to an end item or established baseline and for evaluating these changes prior to approval, while specification maintenance establishes detailed procedures for updating the baselined specifications to reflect the approved changes. Thus, the baselines are meticulously controlled to insure that they do, in fact, accurately represent the system and its end items.

### DESIGN INTEGRITY

Design reviews and inspections (I) provide the procuring agency and the contractor scheduled pauses in the design process for review of the design effort. The Preliminary Design Review (PDR) and Critical Design Review (CDR) provide two reviews of the design process; the PDR at an early stage and the CDR when the detailed design is complete. The First Article Configuration Inspection (FACI)

## ESTABLISHMENT OF BASELINES

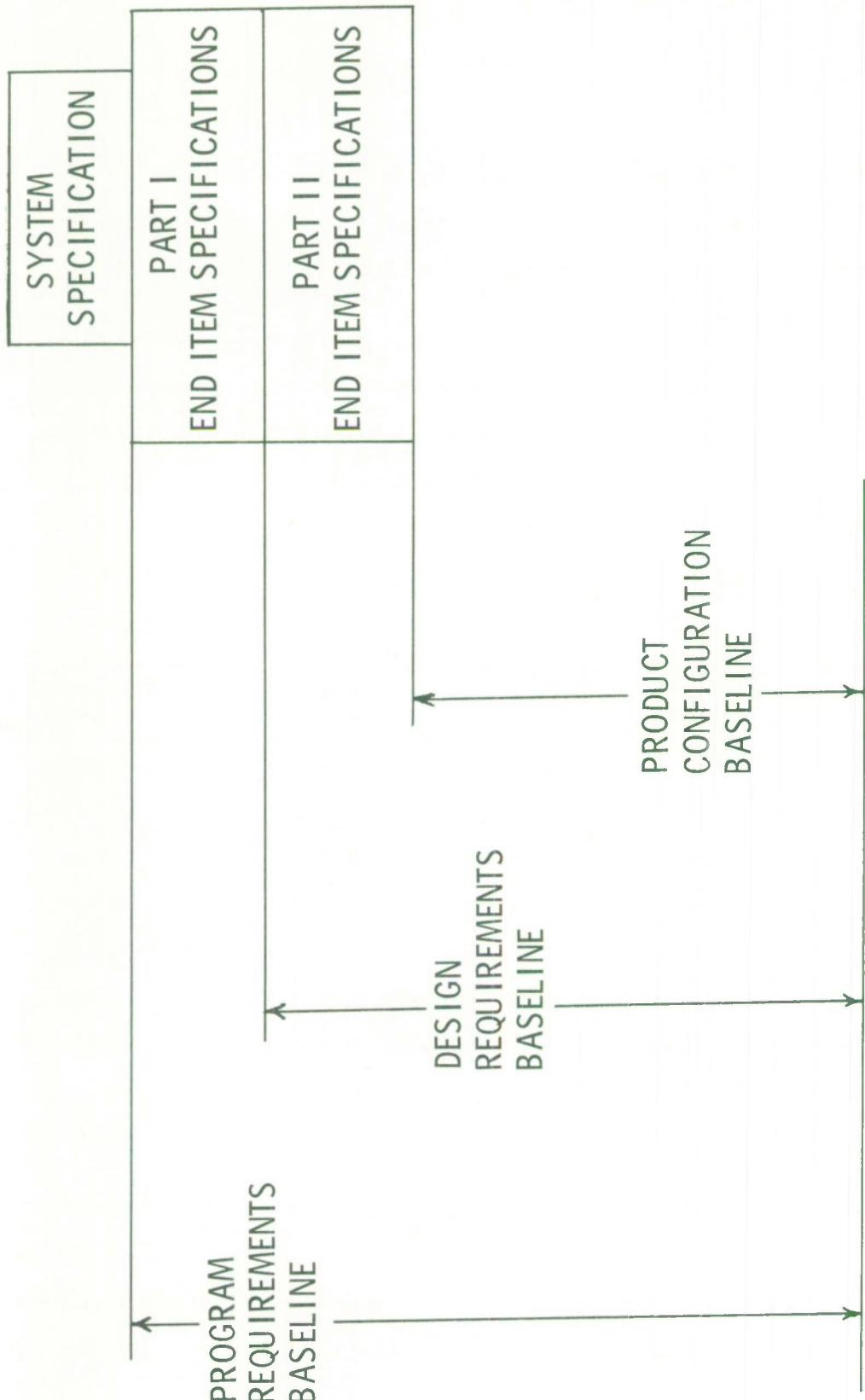


Figure 1

provides an audit of the technical documentation and the qualified computer program to insure that the documentation accurately describes the CPCEI.

The requirement for testing the computer program contract end item is satisfied by a qualification test program based on the Category I tests discussed in AFR 80-14. Each CPCEI qualification test program is conducted to insure that the CPCEI satisfies the design requirements specified. The qualified CPCEIs and CEIs are then evaluated via a Category II test program that tests the total system.

### A TYPICAL COMPUTER PROGRAM ACQUISITION

An examination of the System Life Cycle of a typical computer based command and control system will describe the application of the management techniques to computer program development. The typical system, as described in Figure 2, consists of a number of system segments (1) of which only the information processing segment is germane to this discussion. The information processing system is comprised of equipment contract end items that constitute the computer and its peripheral equipment and one or more computer program contract end items. In the example chosen, two CPCEIs are identified: the Air Defense Computer Program and the Utility Computer Program Package. Other CPCEIs could be Maintenance and Diagnostic Computer Programs, System Exercising and Simulation Computer Programs, Etc.

Early in the Definition Phase (DOD Directive 3200.9, 1 July 1965) the system to be developed is defined by the system specification in terms of system design/performance requirements. The approved system specification technically defines the first baseline, the Program Requirements Baseline, and identifies the

## TYPICAL COMPUTER BASED SYSTEM

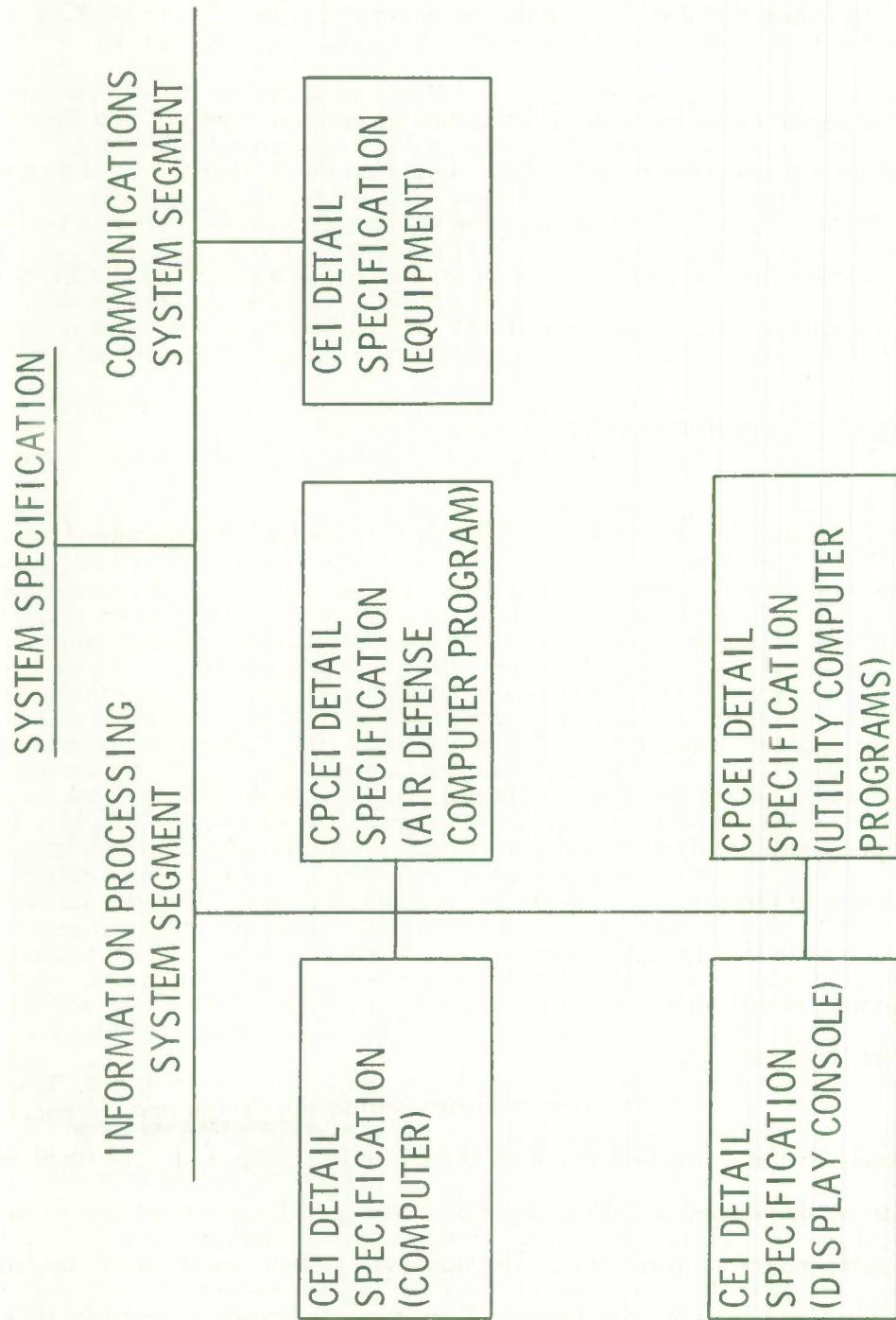


Figure 2

system segments that comprise the system. As a product of the Definition Phase, the definition contractor provides a contract end item detailed specification (Part I) for each contract end item within the system segment for which he is responsible. The approved contract end item specification (Part I) defines the second baseline for each end item, the Design Requirements Baseline. The CPCEI specification (Part I) as shown in Figure 3 fulfills two primary functions. It defines the performance and design requirements for the computer program CEI and it identifies the test requirements that will form the basis for qualification testing of the CPCEI later in the life cycle. Note that the system specification is structured in the same way and performs the same functions at the system level. Within the performance requirements are included the interface requirements of the CPCEI with other equipment and computer program end items. A brief outline of the CPCEI Part I specification is provided in Appendix I. The Part I specification is structured functionally corresponding to the major functions to be performed by the CPCEI. The Air Defense Computer Program for example, would have functions such as aircraft tracking, aircraft identification, weapon control, etc., while the Utility Package would have such functions as assembler, compiler, tape/memory dump, etc. Note that as the detailed design is developed, the CPCEI will be structured into computer program components that satisfy the design requirements of the Part I CPCEI specification. But a one to one relationship between computer program components and functions does not always exist. Any one computer program component may satisfy all, none, or some of the design requirements of a particular function described in the Part I CPCEI Specification. An example of this will be given later in the discussion of the Part II CPCEI Specification.

At the start of the Acquisition Phase, detailed design of the contract end items commences. The functions of the Part I Specification are allocated to the

## RELATIONSHIP OF PART I CPCEI SPECIFICATIONS TO CPCEI DESIGN AND TESTING

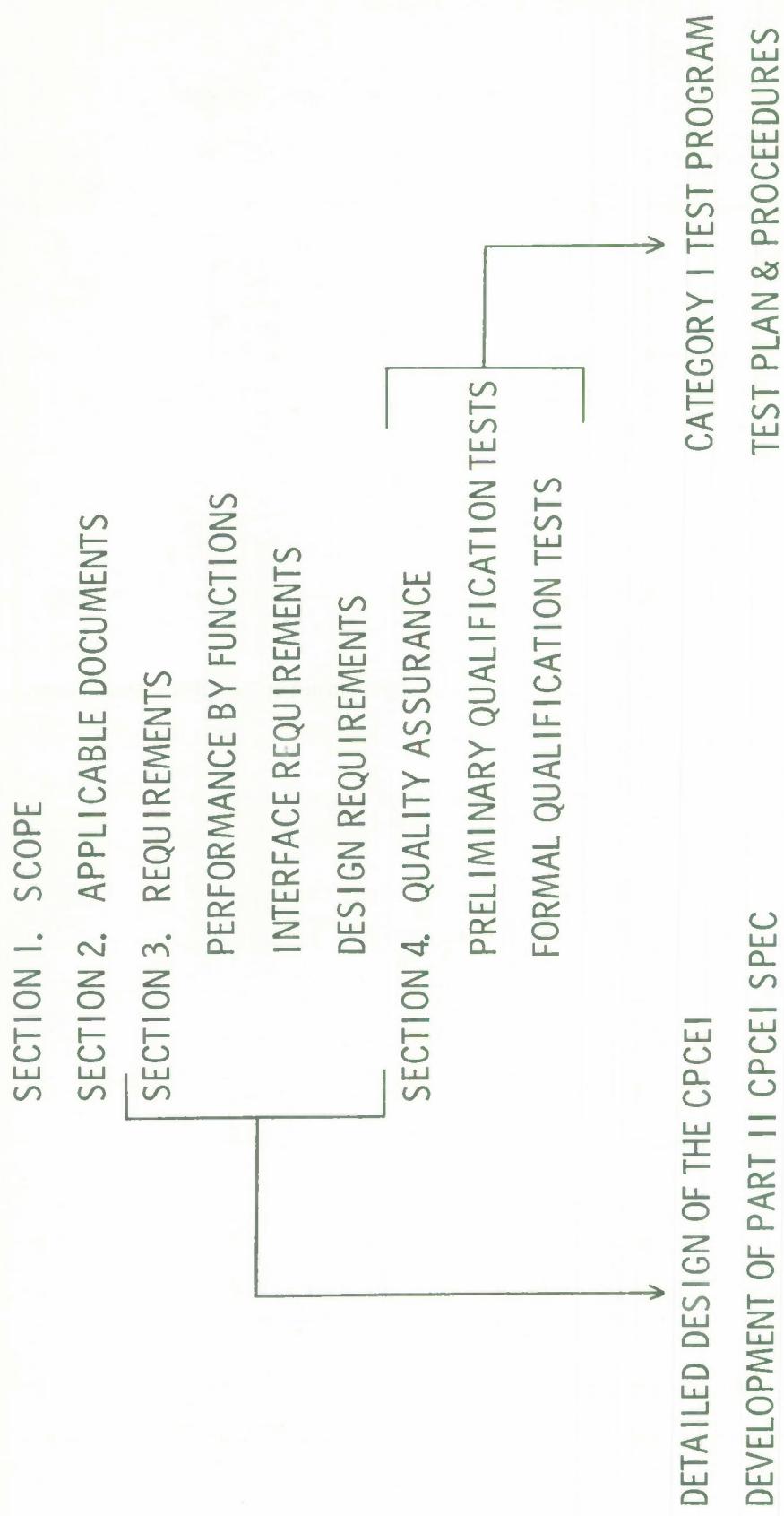


Figure 3

computer program components; the functional flow within the CPCEI is developed; the data base structure is designed, other design activities take place. The documentation of the detailed design from start to finish, i.e., from allocation of functions to complete machine listings, forms the CPCEI specification Part II. The Part II specification is a detailed technical description of the computer program contract end item and evolves as the detailed design progresses from functional flow diagrams, to high level flow charts, to detailed flow charts, to coding of instructions and, finally, to complete machine listings. A number of parallel efforts are conducted as the detail design develops. The Category I qualification test program is being planned and drafts of the test plan and associated test procedures are being written for SPO approval. The relationship of the detailed design and the Category I test program to the Part I CPCEI specification is shown in Figure 3. Supporting documentation such as user's manuals, positional handbooks, simulator guides, etc. are being prepared in draft form as various details of the design become rigid.

The first management milestone in the Acquisition Phase is the preliminary design review (PDR), usually held within 60 days after the contract award for the Acquisition Phase. The PDR may be held for one or more CPCEIs and/or CEIs as required, e.g., a PDR could be held for the whole information processing system segment. At the PDR, the design approach of the CPCEI is reviewed with particular emphasis on the various interface requirements of the CPCEI. The Part I Specification and those portions of the Part II specification that describe the structure and overall functions of the CPCEI form the basis for the PDR. Specifically, the following information would be available for review at a PDR: computer program functional flowcharts; storage allocation charts; control functional description, data base organization and structure. Particular emphasis is placed on the interface requirements of the CPCEI with other CPCEIs and hardware CEIs.

A review of word lengths, message formats, available computer storage, timing, etc. is conducted to insure that the requirements of the Part I CPCEI Specification and the System Specification have been met. At the PDR, interfaces between the CPCEI and equipment CEIs should be sufficiently defined so as to preclude future definition at a lower level of detail. It will be expected, however, that interfaces with other CPCEIs will require subsequent definition at a lower level of detail.

As the design of the CPCEI progresses, the individual computer program components are assigned to groups of individuals for design, flowcharting, coding, etc. Design and development of the computer program components proceeds in a parallel manner from this point on until formal qualification testing. During this design process, the requirements of the Part I specification which are function oriented are translated into the actual CPCEI which is structured into computer program components.

The relationship of the components of a CPCEI to the functions identified in the Part I CPCEI specification is shown in Figure 4. As the design of each component proceeds to the detailed flowchart level, a critical design review is held for that component. In this manner, the CDR for a CPCEI is performed incrementally by computer program components. Due to the varying complexity of the parallel design efforts for computer program components, it would be unreasonable to delay all of the components being developed to hold one CDR for a computer program contract end item.

The critical design review for a CPCEI (2) is a technical review of the design integrity of the CPCEI. The CDR is accomplished incrementally by computer program components when the design is essentially complete, i.e., after

ALLOCATION OF PERFORMANCE FUNCTIONS

TO

AIR DEFENSE COMPUTER PROGRAM COMPONENTS

	ATR	BAG	MIM	RST	•	COMPUTER (M) PROGRAM COMPONENTS
RADAR INPUTS				X		
TRACKING	X		X		X	
IDENTIFICATION		X		X		
DISPLAY			X			
					•	(N) FUNCTIONS

Figure 4

preparation flowcharts but prior to coding of the component. This does not preclude coding portions of complex CPCEIs if necessary to meet schedules. In addition, any coding required to demonstrate design integrity, such as testing of algorithms, may be accomplished prior to CDR. At CDR, the completed sections of the Part II CPCEI specification are reviewed along with supporting analytical data, test data, etc. The compatibility of the CPCEI design with the requirements of the Part I specification is established at CDR. "Inter" interfaces with other CPCEIs and "intra" interfaces between computer program components are examined to insure compatibility. The design integrity is established by review of analytical and test data in the form of logic designs, algorithms, storage allocations and associated methodology. Immediately following the CDR, coding of individual components takes place and the process of checkout and testing of the components begins.

The Category I test program demonstrates that the CPCEI as produced satisfies the design/performance requirements of the Part I CPCEI specification. The Category I test program must be designed to insure that all of the functional requirements, as translated into computer program components, are tested and that nothing gets lost in the translation. The Category I test program is subdivided into two major classes of tests: Preliminary Qualification Tests (PQT) and Formal Qualification Tests (FQT). The Preliminary Qualification Tests are designed to verify the performance of individual components prior to an integrated formal qualification of the complete CPCEI. The PQT is conducted incrementally by components in the same manner as the CDR. Figure 5 depicts the relationship between CDR and the Category I test program. The crosshatched blocks indicate coding of individual computer program components. The CDR, coding and PQT are conducted sequentially on an incremental basis, component

COMPUTER PROGRAM CONTRACT END ITEM  
CRITICAL DESIGN REVIEW AND CATEGORY I TESTS

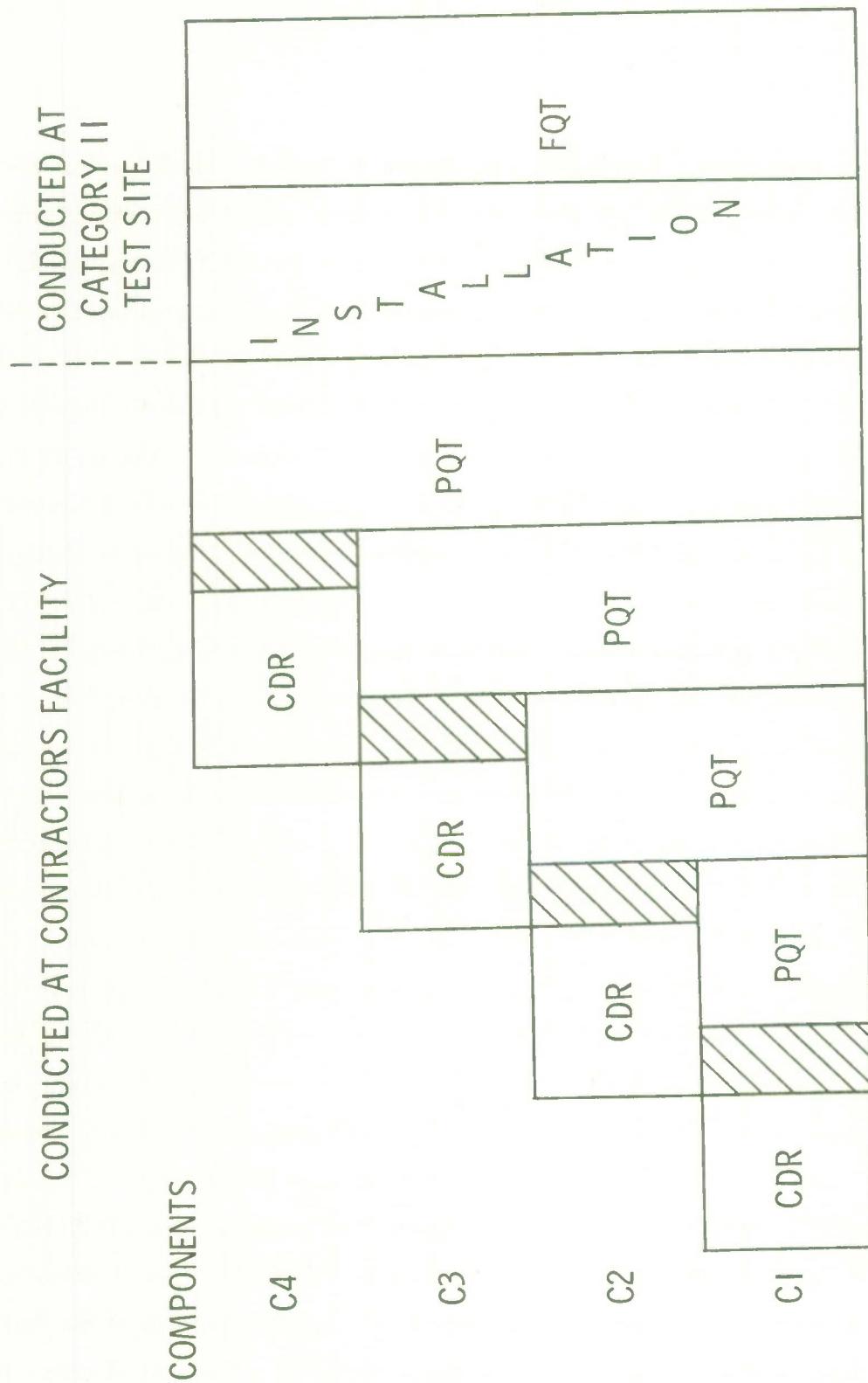


Figure 5

by component. The PQT is modular and a "building block" effect occurs as testing progresses. As each computer program component is added and each PQT conducted increased confidence develops in the CPCEI being tested. At the conclusion of PQT, all of the computer program components have been integrated and tested and the CPCEI is ready for formal qualification and acceptance.

Qualification testing of an operational CPCEI such as the Air Defense Computer Program requires extensive use of simulation techniques. The use of these techniques is dictated by the high cost of providing overhead computer facilities or by the unavailability of new computers undergoing a parallel design and development effort. Although PQT will make maximum use of simulation techniques, the Formal Qualification Tests of an operational CPCEI will require live inputs, live outputs and operationally configured equipment. A prerequisite, then, of FQT is usually the installation and checkout of the CPCEI in an operationally configured computer at the Category II test site. The exception would be in the case of a support CPCEI such as a utility package that would not require live inputs, e.g., radar data, and could be fully qualified at the contractor's facility.

To provide reliable data during FQT, the CPCEI installation requires fully qualified, installed and checked out equipment CEIs. The first opportunity for FQT will occur at the Category II test site after qualified CEIs, that have successfully passed First Article Configuration Inspection, have been installed and checked out and an operationally configured system exists. Subsequently, installation and checkout of the CPCEI occurs and FQT begins. The conclusion of FQT signals the end of the Category I test program. The CPCEI has been fully qualified and all of the requirements of the Part I specification have been satisfied. An exception to this would be those requirements of the Part I specification that could only be demonstrated by a Category II system test.

After a successful FQT, the CPCEI has been fully integrated into the system

and is ready for acceptance. The design and development of the CPCEI is essentially complete except for those residual errors discovered during system testing.

With the design and testing of the CPCEI completed, the CPCEI Specification Part II is available for review. The Part II specification as the detailed technical description of the CPCEI contains the technical discussion of the CPCEI and all of the computer program components that comprise it. It will accompany the CPCEI to each installation or site and function as the primary document for "Maintenance" of the CPCEI. As said before, the technical accuracy and completeness of the Part II specification must be determined prior to its acceptance by the Air Force. The First Article Configuration Inspection (FACI) provides the vehicle for the required review of the Part II specification. The FACI is an audit of the Part II CPCEI specification and the CPCEI as delivered. The result of FACI is the acceptance of the CPCEI specification (Part II) as the technical definition of the third and last baseline, the Product Configuration Baseline. Subsequent to FACI, the configuration of the CPCEI is essentially controlled at the machine instruction level so that the exact configuration of the CPCEI is available for Category II system testing.

At the conclusion of FACI, formal acceptance of the CPCEI takes place. Air Force acceptance of the CPCEI is based on the successful completion of the Category I Test Program and the FACI, but it does not relieve the contractor from meeting the requirements in the system specification. After acceptance, the Air Force, with contractor support, conducts an extensive Category II system test program. The objectives of the Category II tests are to demonstrate that the system will satisfy the system performance/design requirements of Section 4 "Quality Assurance" in the System Specification.

## CHANGE CONTROL AND SPECIFICATION MAINTENANCE

Throughout the design and development process described above, baseline management is required to retain effective control of the process. As stated before, change control and specification maintenance are the primary tools of baseline management. They describe systematic procedures for proposing, approving and implementing changes to an established baseline and associated specifications. Although the level of the change may vary from a system requirements change to a CPCEI instruction change, the procedures are essentially the same. The proposed change is submitted in preliminary form to an Air Force Configuration Control Board (I) who approves or disapproves the proposed change. Once approved, the CPCEI change is developed, coded and tested and the change and appropriate specification change notices (SCNs) are forwarded to the CCB for formal approval. Subsequently, the change is installed in the CPCEI and the SCNs update the appropriate specifications. Figure 6 depicts the ECP/SCN process.

While change control is required for effective system management, excessive control, particularly at the level of computer program instructions, i.e., the product configuration baseline, will restrict the contractors design effort. This is particularly true early in the testing and "debugging" of the CPCEI when numerous errors in coding are discovered and corrections made. By holding the FACI immediately prior to Category II system testing, only the Design Requirements Baseline is established during the design and Category I testing of the CPCEI. Since the number of errors detected throughout the life of a computer program is probably best approximated by an exponential function approaching zero, many of these errors will have been detected prior to FACI. To further prevent overcontrol of the contractors design effort, two classes of changes are defined, the class I

## CLASS I CHANGE PROCESS

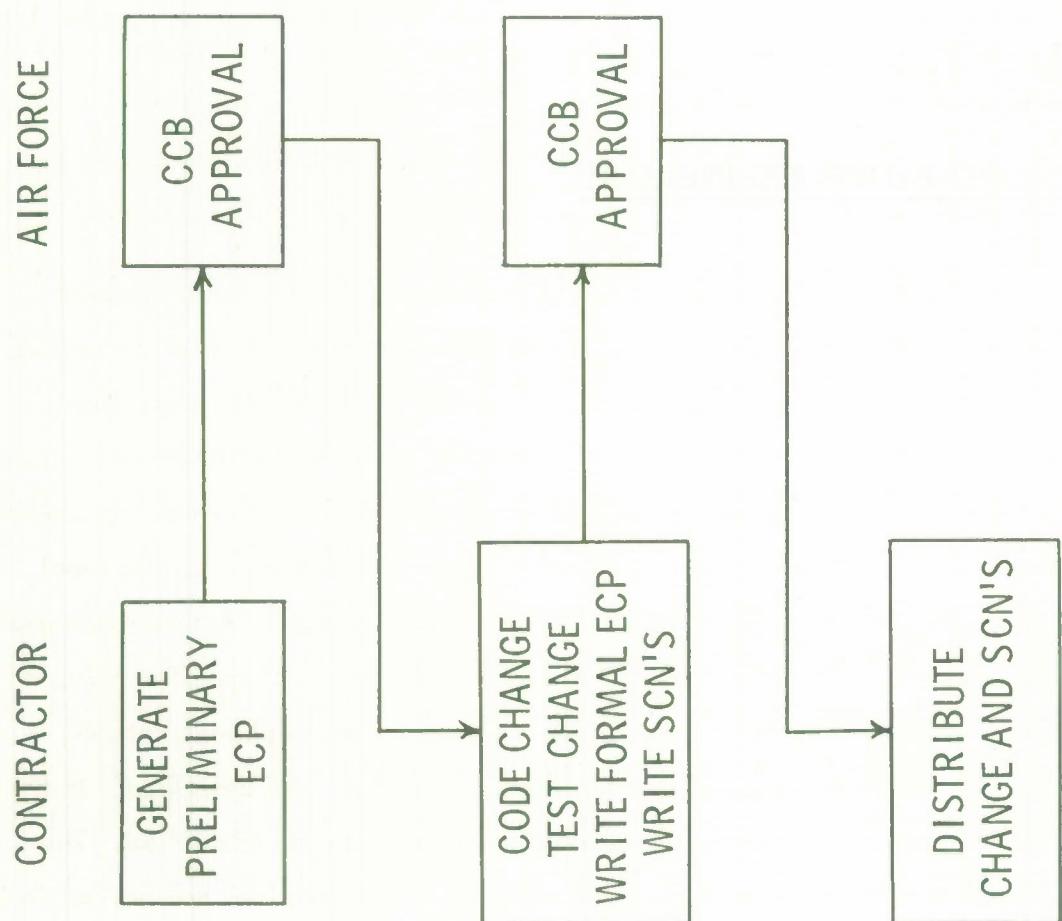


Figure 6

change and the class II change (2,3). A class II change is one which the contractor may effect without prior approval by the configuration control board and at no additional cost to the procuring agency, e.g., changes to correct editorial errors, computer program errors, etc. A class I change which always requires prior approval is any change not falling within Class II as defined above, i.e., a change that effects operational capability as specified in the baselined Part I CPCEI specification, contract price or schedule, interfacing CEIs, etc. The Class I changes are processed as described above, but the class II change is submitted for approval of its classification only after the change is installed but prior to release of the associated SCNs.

#### DOCUMENTATION REQUIREMENTS

As the design process for computer programs evolved and management techniques were applied, specific documentation requirements were uncovered. These documentation requirements were compatible with the Air Force Data Management Program (4) and an effort was made to develop standard data items (4) to describe these requirements. This effort resulted in data items (documentation) falling in four categories: configuration management, handbooks, personnel subsystem and testing. The configuration management items describe the format and minimum content for both Part I and Part II of the CPCEI specification. In addition, various forms for change proposals, specification change notices, specification indexes and specification accounting forms are described. In the handbook category, a number of manuals and handbooks are identified. The Positional Handbook for example, describes all of the functions and actions to be performed by a console operator in a computer based system. On the other hand, the Users Manual outlines the procedures for operating a particular CPCEI. In

the personnel subsystem area, a variety of documents exist that relate the operating personnel to the system. These documents describe various aspects of the personnel interface with the equipment and computer programs from early in the design stage to the training of operators for the system. In the testing area, the documentation requirements for the Category I test plan, test procedures and test report identify the minimum content for these documents. A partial listing of ESD computer program documentation is shown in Table I.

### SUMMARY

The techniques described above have been documented by the Electronic Systems Division in an Exhibit (2) to be used in conjunction with AFSCM 375-1. Basically, the exhibit is a supplement to AFSCM 375-1 and it contains detailed instructions for applying the techniques described in this paper. Although these procedures were developed in conjunction with the AFSC 375 manuals, the concepts can be readily applied to the management of computer programs in general. Additionally, ESD has created a package of unique Forms 9 that supplement the data items provided in AFLCM/AFSCM 310-1 "Management of Contractor Reports and Data." The exhibit and the Forms 9 have been forwarded to Air Force Systems Command for inclusion in future revisions to the basic manuals.

Currently, ESD is selectively applying the exhibit and the Forms 9 to all new procurements involving computer programs. Although experience is limited since all of the contracts are still in the early stages, a number of Preliminary Design Reviews have been held. These reviews have discovered and resolved interface problems between equipments and computer programs that would otherwise have gone undetected. It is felt that the application of these

## ELECTRONIC SYSTEMS DIVISION

### STANDARD DATA ITEMS FOR COMPUTER PROGRAMS

<u>TITLE</u>	<u>ESD #</u>
Part I Specification	236
Part II Specification	237
Minutes of Formal Reviews	289
Category I Test Plan	261
Category I Test Procedure	262
Category I Test Report	263
Positional Handbook	178
Users Manual	290
Computer Programming Manual	288
Synthetic Inputs Operator Guide	282
Exercise Conduct Manual	281

Table I

management techniques to computer based systems will provide a first step in eliminating or reducing those problems discussed earlier. The identification of computer programs as contract end items and the use of uniform specifications will insure that computer program requirements are identified and that the proper emphasis is placed on computer programs early in the design process. With proper emphasis on the computer programs, more realistic trade-offs can be conducted between equipments and computer programs.

The application of baseline management to CPCEIs will insure that when a change in requirements occur, both the reason for the change and the impact of the change is evaluated. Baseline management, if properly applied, will insure that the interfaces between CPCEIs and equipments or personnel are given proper consideration before a change is implemented. The use of design reviews and the modular Preliminary Qualification Tests provide the procuring agency a method of evaluating the design of the CPCEI while gaining confidence in its performance. In addition, potential incompatibilities between equipments and computer programs should be identified earlier in the development cycle and resolved. The result should be smoother integrating of the numerous end items into an operational system. It is hoped that the availability of Standard Forms 9 to provide documentation will eliminate the situation where a computer based system about to go operational, discovers that documentation for the computer program is non-existent or deficient. The addition of these management techniques to the existing 375 series procedures will provide a true systems management program and better equip Air Force Systems Command to acquire computer based systems.

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## APPENDIX I

Section 1	SCOPE
Section 2	APPLICABLE DOCUMENTS
Section 3	REQUIREMENTS
Paragraph 3.1	Performance
Paragraph 3.1.1	System Requirements
Paragraph 3.1.2	Operational Requirements
Paragraph 3.1.2.1	Function 1
Paragraph 3.1.2.1.1	Source and Type of Inputs
Paragraph 3.1.2.1.2	Destination and Types of Outputs
Paragraph 3.1.2.1.3	Information Processing
Paragraph 3.1.2.2	Function 2
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Paragraph 3.1.2.n	Function <u>n</u>
Paragraph 3.1.3	Data Base Requirements
Paragraph 3.1.4	Human Performance
Paragraph 3.2	CEI Definition
Paragraph 3.2.1	Interface Requirements
Paragraph 3.2.1.1	Interface Block Diagram
Paragraph 3.2.1.2	Detailed Interface Definition
Paragraph 3.2.2	Government Furnished Property List
Paragraph 3.3	Design Requirements

Section 4	QUALITY ASSURANCE PROVISIONS
Paragraph 4.1.1	Computer Programming Test and Evaluation
Paragraph 4.1.2	Preliminary Qualification Tests
Paragraph 4.1.3	Formal Qualification Tests
Paragraph 4.2	Category II System Test Program
Section 6	NOTES
Section 10	APPENDIX

## Security Classification

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13. ABSTRACT This paper describes an Electronic Systems Division effort to adapt the AFSCM 375 series and AFSCM 310 series management techniques to computer program acquisition. These techniques are unique in that they provide the first standardized management approach to computer program design and development. A complete process of management procedures that has been developed for management of computer programs during definition and acquisition phases is discussed. Particular emphasis is placed on an extensive change package to AFSCM 375-1 <u>Configuration Management During Definition and Acquisition Phases</u> and a package of computer program data items for insertion in AFSCM/AFLCM 310-1 <u>Data Management</u> proposed by Electronic Systems Division of AFSC. The concepts of uniform specifications, baseline management, change control, specification maintenance and accounting and standard data items as they apply to computer programs are discussed and the impact of applying these techniques to System Programs is analyzed.		

Security Classification

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